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Opportunities for growing of garden pea in organic production systems

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Abstract

The purpose of this study was to assess a complex of characteristics of garden pea (*Pisum sativum* L.) lines grown under organic farming conditions. A field experiment involving three production systems (two organic and conventional) evaluated the productivity, disease and pest infestation and seed quality in four garden pea accessions. The experiment was conducted in the Maritsa Vegetable Crops Research Institute in Plovdiv, Bulgaria during the period 2016–2017. The expression of the studied characteristics in the three production systems was different and was determined by the genetic features of the tested pea lines. Lines 1855_3 and 101i produced a higher average yield of green grain in organic 2 treatment with use of organic fertilization products authorized for organic production and with use of biopesticides for plant protection. Low degree of infestation by Fusarium wilt (*Fusarium oxysporum* f. sp. *pisi*), bacterial blight (*Pseudomonas syringae* pv. *pisi*), Alternaria blight (*Alternaria* spp.), downy mildew (*Peronospora pisi*) and species of pea moths (*Laspeyresia* spp.) was established in the garden peas grown in different treatments of organic and conventional production. Higher degree of infestation by Ascochyta blight (*Ascochita pisi*) and higher percentage of seeds, damaged by pea weevil (*Bruchus pisi*) were established in the organic treatment. The influence of pathogens and pests on the studied lines was limited as a result of application of biohumus and biopesticides. It was found that the seeds from garden pea, grown in the organic treatment had lower absolute seed weight compared to the seeds grown in the conventional treatment. The seed germination was high in the organic production systems for lines 1857_3 and 73_{10}.

Key words: biofarming, breeding, disease, pest, *Pisum sativum*, yield

Introduction

The organic farming is one of the most dynamic sectors of European agriculture, with agricultural land used for it increasing by about 400 000 hectares per year. The organic market in the European Union is worth about 27 billion euros – 125% more than ten years ago (*Гребеничарски*, 2016; Organic farming statistics, 2017; http://ec.europa.eu/eurostat). Some of the basic principles of organic production are as follows: balanced use of water, soil and genetic resources; ban on the use of synthetic fertilizers and pesticides; use of varied crop rotation, saturated with leguminous crops; production adapted to local agro-climatic conditions, breeds of animals and plant cultivars with minimal negative effect on the natural environment (Kostadinova, Popov, 2012).

In this regard, the pea as a legume is gaining popularity in the organic production because of its nitrogen fixation properties, market potential and good economic return (Fernandez et al., 2012). Research has been conducted on optimal sowing rates (Baird et al., 2008), weed, disease and pest control (Annicchiarico, Filippi, 2008; Stanley, 2016; Georgieva, 2017), the use of organic fertilizers and stimulants in the conditions of organic production (Georgieva et al., 2017). The productivity of local and introduced cultivars and lines of peas in organic conditions (Gopinath et al., 2009; Chadha et al., 2013; Georgieva et al., 2015) was determined. Strategies, methods, technologies and protocols for organic testing and Production Guide for Organic Peas for Processing have been developed (Lammerts Van Bueren, Struik, 2004; Seaman, 2016).

Among the European Union countries, Bulgaria is one of the leaders according to the increasing number of organic producers. The number of organic farmers reached nearly 7,000 at the end of 2016, and certified organic production area totalled over 60,000 hectares (Кабакчиева, 2017). Bulgaria (+59%) is one of the top three countries in Europe with growth of organic farmland (2014–2015) after Serbia (+60%), with 8.2% growth in Europe and 7.8% in the European Union (The World of Organic Agriculture, 2017).

At the end of 2017, the European Council of Agricultural Ministers agreed on a new Council Regulation, which provides that the seeds and plant reproductive material for organic farmers are to be organically certified after 2020 (GAIN Report, 2017). The interest in organic production and the new Council Regulation require creation of local cultivars with highly adaptive potential, focusing on the stability of genotypes, not on their higher productivity. Certified organic seeds are grown in organic soil and are only exposed to products (like fertilizer and pest control) permitted by the U.S. Department's of Agriculture (USDA's) National Organic Program during its growing, processing, and packaging periods.

The biological reactions of genotypes of pepper, garden pea, head cabbage and potato to organic

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production conditions have been evaluated in recent years in Maritsa Vegetable Crops Research Institute, Bulgaria. The obtained initial results suggest that there are opportunities for the development of organic production of these vegetables in Bulgaria, as the genotypes exhibited a relatively high productivity level (Kalapchieva et al., 2011; Antonova et al., 2012; Todorova, Filyova, 2014; Nacheva et al., 2015).

Preliminary assessment of the genotype and environment interaction is an important factor for genetic progress (Crespo-Herrera, Ortiz, 2015). The obtained results showed a strong influence of the genotype on the phenotypic expression of the seed characteristics: seed number per pod, absolute seed weight and seed yield per plant (Kalapchieva, Yankova, 2014). The variability of the seed germination depends to a great extent on the interaction of genotype and conditions of the year.

The purpose of this study was to evaluate a complex of characteristics: productivity, disease and pest infestation and seed quality of garden pea lines under organic farming conditions.

Materials and methods

The study was conducted during the period 2016–2017 in the experimental fields of the Maritsa Vegetable Crop Research Institute, Plovdiv, Bulgaria with four garden pea (*Pisum sativum* L.) accessions: an early line 73_{10}, medium-early lines 1855_3, 1857_3 and 101i in two organic production systems: organic 1 – growing plants under natural soil fertility without using plant protection products, organic 2 – growing plants with use of organic fertilization products authorized for organic production and with use of biopesticides for plant protection; the control treatment of the experiment was conventional production growing with application of herbicides, mineral fertilization and plant protection with chemical fungicides and insecticides.

The sowing was carried out in the 1st ten-day period of March on a high flatbed by scheme 80 + 20 + 40 + 20 / 4–5 cm (4 rows high flat bed – 160 cm width); the seeds were planted in two couples of double rows 40 cm apart. The distance between the seeds in the row was 4–5 cm, and the distance between the rows in the couple was 20 cm. The experiments were laid out in a randomized complete block design with three replicates. Plot size was 1.6 × 4.0 m with 20 seeds in a metre in a row. The fertilization rates with biohumus were determined in the Agrochemical Laboratory of the Maritsa Vegetable Crop Research Institute, Bulgaria. Fertilizer rates were adjusted according to the soil nutrient status and the biological requirements of garden pea. The results of the preliminary analysis of nutrient status in the soil in the conventional and organic plots are presented in Table 1.

Before the flowering, in the organic 2 treatment fertilization with biohumus was conducted at a rate of 1500 L ha^{-1} (2016) and 2000 L ha^{-1} (2017). The biohumus was spread on the surface and mixed with the topsoil. For pest and disease control the following plant protection products were applied: Pyrethrum FS EC 0.05% (a.i. pyrethrin, extract from *Chrysanthemum cinerariefolium*), Piros 0.08% (a.i. pyrethrin, extract from *Chrysanthemum cinerariefolium*), Neem Azal T/S 0.3% (a.i. azadirachtin, extract from *Azadirachta indica*) and Timorex 0.1% (extract from *Melaleuca alternifolia*). The chemical products, used in the control treatment were the following ones: Decis 2.5 EC 0.04% (a.i. deltamethrin), Nurele Dursban 0.07% (a.i. cypermetrin + chlorpyrifosetyl) and Mospilan 20 SP 0.0125% (a.i. acetamiprid).

Table 1. Soil acidity (pH) and concentrations of basic nutrients before trial establishment

Year	Treatment	pH	EC ms cm^{-1}	NO_3 ppm	P ppm	K ppm	Ca ppm	Mg ppm
2016	organic	6.38	0.068	5.0	8.6	16.6	16.0	12.0
	conventional	6.22	0.36	2.0	28.6	68.1	48.0	24.0
2017	organic	6.41	0.062	7.0	11.3	1.7	36.0	16.8
	conventional	6.22	0.11	2.0	10.4	43.2	16.0	4.8

EC − electrical conductivity

At technological maturity the following basic biometric parameters of an average sample, containing 15 plants per treatment were assessed individually: plant height (cm), height of the first pod (cm), number of unproductive nodes, total number of nodes per plant, number of pods per plant, weight of pods per plant (g), grain weight per plant (g), and average number of grains per pod. The yield of green pods (kg ha^{-1}) and green grain (kg ha^{-1}) was estimated.

The following characteristics of plants at the beginning of technological maturity were recorded: the degree of disease infestation – Fusarium wilt (*Fusarium oxysporum* f. sp. *pisi*), Alternaria blight (*Alternaria* spp.), Ascochyta blight (*Ascochyta pisi*), downy mildew (*Peronospora pisi*) and bacterial blight (*Pseudomonas syringae* pv. *pisi*). Both the percentage of pods per plant damaged by pea moths (*Laspeyresia* spp.) at the technological maturity and the percentage of seeds damaged by pea weevil (*Bruchus pisi* L.) at the botanical maturity was recorded. The recording was performed on an average sample of 500 seeds 60 days after harvesting.

The following quality indicators of seeds, obtained from the organic production systems: absolute seed weight (g), germination energy (%) and germination (%), was studied. The absolute seed weight was analysed for 1000 dry seeds. Germination energy, the speed at which seeds germinate, sometimes expressed as a percentage of seeds germinated within the first week (on the 8th day) of analysis with respect to the total number of seeds to germinate was recorded in two samples of 100 seeds (25 seeds per replication). The seed germination was recorded on the 12th day of the experiment.

The obtained experimental data were statistically processed using the software *Excel*, programme *SPSS*, version 12 (IBM Corp., USA). The influence of variation factors on studied characters has found.

Results and discussion

The morphological characters of the studied garden pea lines showed different manifestations in the organic and conventional treatments (Table 2). It was established that in line 1885_3 the plant high was lower and the number of unproductive nodes was higher in the organic treatment. There are no proven differences for the other characters in the same line. In line 101i, grown in organic 1 treatment lower values of characteristics: pod number per plant, pod weight per plant and green grain weight, in comparison with the conventional treatment were observed.

The highest green grain weight per plant 26.7 g was recorded for line 1857_3 in organic 2 treatment with application of biohumus and plant protection (Table 2). In the same system, line 101i was characterized by a higher productivity than that in the organic 1 treatment with natural soil fertility and no use of plant protection products. The other two lines were more productive in organic 1 treatment but did not exceed weight of green grains per plant in the conventional treatment.

Plant breeding for organic farming can reduce the yield gaps between both production systems, conventional and organic farming. The yield differences are usually in favour of conventional production. Crespo-Herrera and Ortiz (2015) reported that in fruit and oilseed crops organic yields was 3% and 11% lower than in conventional treatment, respectively; while cereals and vegetables had 26% and 33% yield reduction in organic system. Results of the three of the investigated lines

Table 2. Mean data of morphological characters of garden pea lines grown in the organic and conventional production systems, 2016–2017

Treatment	Plant height cm	Height to first pod cm	Number of unproductive nodes	Number of nodes per plant	Number of pods per plant	Weight of green pods per plant g	Weight of green grains per plant g	Average number of grains per pod
Line 1855_3								
Control	95.7 a	55.7 ns	13.2 b	19.8 a	10.0 ns	51.3 ns	21.9 a	8.2 ns
Organic 1	85.9 b	55.5 ns	14.7 a	20.2 a	8.7 ns	48.5 ns	19.6 ab	7.7 ns
Organic 2	85.5 b	57.5 ns	13.3 a	18.8 b	9.3 ns	40.6 ns	16.2 b	8.0 ns
Line 1857_3								
Control	82.2 ns	50.1 ns	14.9 ns	20.1 ns	10.3 ns	48.9 ns	21.1 ns	8.0 ns
Organic 1	77.6 ns	51.9 ns	14.1 ns	20.0 ns	8.6 ns	37.7 ns	14.9 ns	8.1 ns
Organic 2	79.2 ns	50.9 ns	14.9 ns	20.1 ns	10.2 ns	48.3 ns	26.7 ns	8.0 ns
Line 101i								
Control	89.9 ns	55.0 ns	14.3 ns	21.2 ns	12.8 a	67.8 a	28.1 a	7.7 ns
Organic 1	79.9 ns	53.3 ns	15.3 ns	21.5 ns	8.7 b	44.7 b	17.1 b	7.7 ns
Organic 2	82.7 ns	56.2 ns	14.8 ns	20.8 ns	10.8 ab	51.6 ab	22.4 ab	7.7 ns
Line 73_{10}								
Control	64.0 b	26.7 ns	8.5 ns	15.8 ns	18.0 ns	53.7 ns	24.1 ns	5.7 b
Organic 1	77.9 a	29.4 ns	8.2 ns	17.3 ns	15.5 ns	46.6 ns	20.1 ns	6.5 a
Organic 2	64.0 b	25.8 ns	7.8 ns	16.3 ns	12.2 ns	34.5 ns	16.6 ns	5.5 b

a, b… – Duncan's multiple range test ($p < 0.05$), ns – not significant

(1855_3, 101i and 73_{10}) of garden pea also showed lower productivity in organic treatment. Line 1857_3 confirms other studies, which suggest that in both systems yields can come close. According to Denison et al. (2004), the trends in organic maize yields were also significantly negative, but yields of tomatoes in the same system showed a significant positive trend. The breeding for organic production aims to fit cultivars into farming systems relying on renewable organic resources. The choice of appropriate cultivars is crucial for a well-functioning system in organic farming.

Georgieva (2017) reported that a local pea cultivar with a complex of features: high yield combined with a longer growing period, an average ecological stability, medium resistance to downy mildew and a high nitrogen content of the biomass, suitable for growing in organic production is available. The lines developed in Bulgaria, which are studying, also show good yields in the different organic production systems no proven differences with conventional yields. The mid-early line 1857_3 could be applied with priority in the Bulgarian pea breeding, because it was characterized by higher individual productivity of green grain weight per plant.

The variation of the majority of the studied morphological characters was determined mainly by the genetic differences of the pea genotypes included in the study (Table 3). An exception was green grain weight per plant for which the year, treatment and their interactions with the genotype were determinative, as well as the interaction between three factors. The factor treatment (C) has an influence manly on the manifestation of the following characters: pod number, pod weight and green grain weight per plant.

Table 3. Analysis of variance of morphological characteristics of the genotypes of garden pea the organic and conventional production systems

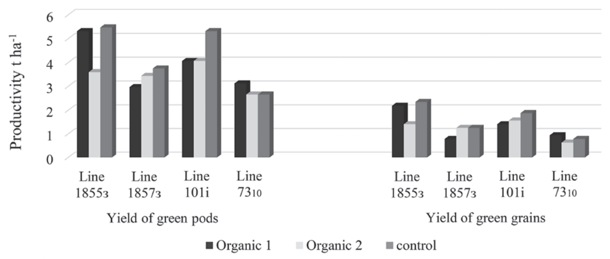
Sources of variation	df	Plant height	Height to first pod	Unproductive nodes	Nodes per plant	Pods per plant	Weight of green pods per plant	Weight of green grains per plant	Average number of gains per pod
Genotype (A)	3	1367.6***	3295.0***	172.7***	71.7***	132.3***	387.4*	34.2 ns	18.2***
Year (B)	1	289.2*	9.1 ns	4.1 ns	25.0**	6.0	696.0*	256.4*	13.6***
Treatment (C)	2	156.6*	3.8 ns	2.1 ns	3.2 ns	42.7**	1036.3**	207.1*	0.2 ns
A × B	3	59.2 ns	73.5**	2.1 ns	3.8 ns	9.7 ns	249.0 ns	117.9*	1.5*
A × C	6	208.2**	13.8 ns	1.9 ns	1.3 ns	14.4*	265.6*	105.6*	0.6 ns
B × C	2	425.6***	277.2***	2.6 ns	5.6*	12.1 ns	121.9 ns	1.42 ns	0.7 ns
A × B × C	6	134.8*	11.4ns	2.5 ns	3.3 ns	28.6**	436.1**	125.4*	0.4 ns
Within	48	47.1	15.4	1.7	2.0	7.4	132.9	51.6	0.4

df – degree of freedom; *** – $P \leq 0.001$, ** – $P \leq 0.01$, * – $P \leq 0.05$, ns – not significant

It is important to evaluate genotype × environment and genotype × treatment interactions as part of organic farming focused breeding programs like in conventional breeding programs (Lammerts van Bueren et al., 2011). For example, for wheat, indirect selection under conventional high-input conditions is quite effective for traits with high heritability, including early maturity, plant height and 1000 kernel weight. However, this is not necessarily the case for quantitative traits characterized by high interaction of genotype × environment, like grain yield or end-use quality traits. Our studies confirmed the determinant role of the genotype × environment and genotype × treatment interactions as well as the A × B × C interaction in the green grain yield for direct selection. The independent influence of the factors year (B) and treatment (C) must also be taken into account, as they are leading. Based on a study of a segregating spring wheat population tested under organic and conventional farming conditions, Reid et al. (2009) clearly demonstrated the superiority of direct selection (under organic farming) compared with indirect selection (under conventional farming) for grain yield and yield components. Therefore, it is necessary to select under organic management at least in the advanced breeding generations. The advanced line 1857_3 of garden pea used in the study demonstrated relatively high individual productivity and the possibility of direct selection for this indicator.

The yield of green pods and green grain per hectare in the conventional treatment was naturally the highest in three of the studied lines, and only line 73_{10} was distinguished by higher yields reported in organic 1 treatment with natural soil fertility without the use of plant protection products (Fig.). There were no proven differences in yields between the treatments of growing for the four lines. Lines 1855_3 and 101i were identified as promising by average yields over the two years.

Murphy et al. (2007) used analysis of variance to test for significant genotype system interactions between organic and conventional growing systems. Their results indicate that conventional system yielded higher than organic for two locations, and no differences between systems for yield were observed in three locations. In this study only line 73_{10}, grown in organic 1, exceeded the yield obtained in the conventional treatment.



a, b… – Duncan's multiple range test ($p < 0.05$), ns – not significant

Figure. Productivity of garden pea lines grown in the organic and conventional production systems (average of 2016–2017)

For the other genotypes, higher yields were produced in the conventional production system.

Performance (yield, yield stability and quality) is also linked to tolerance to abiotic and biotic stress, which is a complex of inherited traits with high genotype and environment interactions, resulting in the masking of the genotypic value of breeding lines.

Phytopathological and entomological investigation and observations showed that during the period of the study a slight infestation by *Fusarium oxysporum* f. sp. *pisi*. *Pseudomonas syringae* pv. *pisi*, *Alternaria* spp., *Peronospora pisi* and higher infestation by *Ascochita pisi* were established (Table 4). The presence of pathogens was determined macroscopically, microscopically and on an artificial nutrient medium.

Pseudomonas syringae pv. *pisi* and *Alternaria* spp. are recorded for in the first year, as *Pseudomonas syringae* pv. *pisi* appeared only at the second assessment (Table 4). The highest infection level caused by *Pseudomonas syringae* pv. *pisi* was observed in line 1855_3, while *Alternaria* spp. was expressed in a greater degree in line 73_{10}. Probably the reason for the high percentage of infested plants in the conventional treatment is lack of control on this disease.

During the second year, *Fusarium oxysporum* sp. *pisi*, *Ascochita pisi* and *Peronospora pisi* were reported. At the first assessment, it was established that the infestation by *Ascochita pisi* was more strongly expressed than the infestation by *Fusarium oxysporum* sp. p*isi*. The highest index of infestation caused by *Ascochita pisi* was recorded for lines 1857_3 and L 73_{10} in natural soil fertility. The highest degree of infection by *Fusarium oxysporum* sp. *pisi* was recorded in line L 73_{10} in natural soil fertility. The second assessment was performed 7 days after the first one during which the presence of another pathogen *Peronospora pisi* was established. *Ascochita pisi* and *Fusarium oxysporum* sp. *pisi* were detected again, and there was a gentle increase in the index of infestation compared with the previous assessment. Line 73_{10} was infested most strongly by *Peronospora pisi* in the soil of natural fertility, while the lowest degree of infestation by *Peronospora pisi* was observed in line 101i in the control treatment. The influence of pathogens on the tested lines was limited in organic 2 with biohumus fertilization and treatment with biological plant protection products as well as in the control treatment with application of chemical products.

In the first year, slight infestation by pea moths of the genus *Laspeyresia* spp. (Lepidoptera) was observed, while in the second year of investigation the infestation was almost zero (Table 5). Maximal values (16.6% and 2.9%) of pea moth infestation were reported for line 101i in the both organic treatments during the first year of the study and for line 1857_3 in organic 1 (natural soil fertility without the use of plant protection products) during the second year.

The infestation by *Bruchus pisi* in the organic treatment (from 49.2% for line 73_{10} in 2016 to 85.0% for line 1857_3 in 2017) for all lines was higher than that reported for the conventional treatment (8.8% for 1857_3 in 2016 – 35.7% for line 1855_3 in 2017). The percentages of seeds damaged by *Bruchus pisi* were relatively lower during the first year and in organic 2 treatment for the two years of the experiment.

The study of Georgieva et al. (2015) showed that the use of organic products (Biofa + Pyrethrum) in field pea

Table 4. Degree of disease infestation (%) of garden pea lines grown in the organic and conventional production systems

Treatment	2017			2016	
	Ascochita pisi 1st / 2nd assessment	*Fusarium oxysporum* sp. *pisi* 1st / 2nd assessment	*Peronospora pisi* 1st / 2nd assessment	*Pseudomonas syringae* pv. *pisi* 1st / 2nd assessment	*Alternaria* spp. 1st / 2nd assessment
Line 1855_3					
Control	3.8 c / 4.6 c	0.1 b / 0.2 b	– / 1.9 c	– / 3.7 a	2.0 ns / 1.7 ns
Organic 1	6.2 a / 7.2 a	0.8 a / 1.4 a	– / 3.0 a	– / 3.7 a	1.0 ns / 2.3 ns
Organic 2	4.8 b / 6.0 b	0.6 b / 0.3 b	– / 2.5 b	– / 2.3 b	2.0 ns / 2.7 ns
Line 1857_3					
Control	3.1 b / 4.2 b	0.2 b / 0.4 b	– / 1.7 b	– / 3.3 ns	1.3 ns / 2.3 ns
Organic 1	7.0 a / 7.4 a	1.2 a / 1.4 a	– / 2.8 a	– / 3.3 ns	1.0 ns / 1.7 ns
Organic 2	4.2 b / 5.0 b	0.5 b / 0.7 ab	– / 2.5 a	– / 2.3 ns	1.3 ns / 2.0 ns
Line 101i					
Control	3.8 c / 4.8 c	0.1 b / 0.3 b	– / 1.5 b	– / 2.7 ns	1.7 ns / 1.7 ns
Organic 1	6.2 a / 7.7 a	1.2 a / 1.4 a	– / 2.3 a	– / 2.7 ns	1.0 ns / 2.0 ns
Organic 2	5.5 b / 6.5 b	0.4 b / 0.5 ab	– / 1.5 b	– / 2.7 ns	1.7 ns / 2.3 ns
Line 73_{10}					
Control	4.2 b / 5.6 b	0.3 b / 0.3 b	– / 1.6 a	– / 2.0 ns	3.0 ns / 2.3 ns
Organic 1	6.9 a / 8.0 a	1.7 a / 2.3 a	– / 3.1 a	– / 2.7 ns	2.7 ns / 2.7 ns
Organic 2	5.1 b / 6.2 b	0.3 b / 0.6 b	– / 2.3 b	– / 2.0 ns	2.7 ns / 3.0 ns

a, b… – Duncan's multiple range test ($p < 0.05$), ns – not significant

cultivation gives promising outcomes. The most valuable treatment, which combined high stability, productivity and protection against the *Bruchus pisi*, has been the one with applying twice the mixture of bio-fertilizer and bioproducts for plant protection. In our investigation, the values giving information about *Bruchus pisi* and *Ascochita pisi* infestation in the treatments with bioinsecticide application were lower for all studied lines than in the organic 1. However, the infestation by *Bruchus pisi* and *Ascochita pisi* in the organic treatment for all lines was higher than that for the conventional treatment. Further investigations are indispensable to expand the range of products (bioinsectides, biofertilizers and growth regulators), which provide good insect control, high productivity and stability under organic farming conditions.

The results of absolute seed weight, germination energy and germination of seeds obtained in the organic and conventional growing systems are presented in Table 6.

A significant difference in the absolute seed weight in conventional and organic treatments was established, and this difference between organic 1 and 2 was in line 101i only. Lines 1855_3 and 101i showed low values for germination energy and germination in both organic treatments. The line 101i was characterized by values lower and in the conventional treatment compared to the other three lines.

Table 5. Percentage of pods damaged by *Laspeyresia* spp. and seeds damaged by *Bruchus pisi* of garden pea lines grown in the organic and conventional production systems

Treatment	2016		2017	
	Laspeyresia spp.	*Bruchus pisi*	*Laspeyresia* spp.	*Bruchus pisi*
		Line 1855_3		
Control	0.0 b	10.4 c	0.0 ns	35.7 b
Organic 1	3.8 a	64.6 a	0.0 ns	74.7 a
Organic 2	0.0 b	51.2 b	0.0 ns	64.7 a
		Line 1857_3		
Control	0.0 b	8.8 c	0.0 b	24.3 b
Organic 1	3.5 a	75.8 a	4.2 a	85.1 a
Organic 2	0.0 b	58.4 b	0.0 b	81.3 a
		Line 101i		
Control	0.0 c	26.4 c	0.0 ns	24.3 c
Organic 1	16.6 a	76.4 a	0.0 ns	78.0 a
Organic 2	2.9 b	71.8 b	0.0 ns	66.3 b
		Line 73_{10}		
Control	0.0 b	24.4 c	0.0 b	22.0 c
Organic 1	3.3 a	62.0 a	1.7 a	82.3 a
Organic 2	0.0 b	49.2 b	0.0 b	68.0 b

a, b… – Duncan's multiple range test ($p < 0.05$), ns – not significant

Table 6. Seed characteristics of garden pea lines grown in the organic and conventional production systems

Treatment	Absolute seed weight g	Germination energy %	Seed germination %
		Line 1855_3	
Control	166.8 a	91.0 a	92.8 a
Organic 1	141.9 b	68.7 ab	76.7 ab
Organic 2	145.3 b	65.3 b	68.2 b
		Line 1857_3	
Control	170.4 a	88.5 ns	96.2 ns
Organic 1	141.2 b	89.3 ns	93.0 ns
Organic 2	152.1 b	86.2 ns	90.3 ns
		Line 101i	
Control	178.0 a	76.8 ns	84.7 ns
Organic 1	135.7 c	66.0 ns	75.3 ns
Organic 2	158.8 b	63.5 ns	78.5 ns
		Line 73_{10}	
Control	151.6 a	84.7 ns	95.8 ns
Organic 1	133.9 b	91.5 ns	95.7 ns
Organic 2	140.6 b	80.0 ns	89.7 ns

a, b… – Duncan's multiple range test ($p < 0.05$), ns – not significant

One of the very few studies comparing seed quality from the different production systems, Capouchova et al. (2012) in the Czech Republic, found no significant differences in the biological traits between conventional, organic and farm saved oat seeds. Although there was a tendency towards higher germination, energy of germination and 1000 grain weight in conventional seeds compared to organic and farm saved seeds. In most studies, no differences were found in quality of seeds from organic and conventional production (Sundheim et al., 2014).

The variation in the values of germination energy and germination (17.06% and 24.15%, respectively) was caused by the genetic differences of the studied lines (Table 7). The different growing systems had effect (45.69%) on the variation of absolute seed weight. The factor genotype (24.15%) and the interaction genotype and treatment (14.97%) are the reason for the variation in the absolute seed weight.

Table 7. Power of influence (%) of variation factors on the seed characteristics of garden pea lines grown in the organic and conventional production systems

Factor	Absolute seed weight	Germination energy	Seed germination
Genotype	11.16**	17.06**	24.15***
Treatment	45.69***	6.24*	ns
Genotype × treatment	ns	ns	14.97*

*** – $P \leq 0.001$, ** – $P \leq 0.01$, * – $P \leq 0.05$, ns – not significant

Georgieva et al. (2017) reported a positive effect of the application of organic nano-fertilizers on *in vitro* pollen germination and pollen tube elongation in *P. sativum* and the consequences of using nano-fertilizers in organic system. In the future, more detailed research is needed to clarify the mechanism of action, the consequences of using nano-fertilizers and their influence on seed characteristics.

Conclusions

1. The green grain yield of the four studied garden pea lines grown in the organic production system ranged from 0.63 t ha^{-1} for line73_{10} to 2.19 t ha^{-1} for line 1855_3.

2. A significant difference in the absolute seed weight was established between conventional and organic treatments. The seed germination in the organic system was lower; it varied from 68.2% to 95.7%.

3. The garden pea line 1855_3 was identified as promising for growing in the organic production system with higher average yields and comparatively low degree of infestation by *Fusarium oxysporum* f. sp. *pisi*, *Bruchus pisi* and *Laspeyresia* spp.

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Žirnių auginimas taikant ekologinę auginimo sistemą

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Santrauka

Tyrimo tikslas – įvertinti daržo žirnio (*Pisum sativum* L.), auginto ekologinio ūkininkavimo sąlygomis, linijų savybes. Lauko eksperimente buvo tirtos trys žirnių auginimo sistemos – dvi ekologinės ir viena tradicinė, vertintas keturių daržo žirnio linijų produktyvumas, ligos bei kenkėjai ir sėklų kokybė. Tyrimas buvo atliktas Maritsa daržovių tyrimų institute Plovdive, Bulgarijoje, 2016–2017 m. Trijose auginimo sistemose tirtų savybių išraiška skyrėsi ir buvo nulemta daržo žirnio linijų genetinių savybių. Linijų 1855_3 ir 101i didesnis vidutinis žalių žirnių derlius gautas taikant 2 ekologinę sistemą: tręšiant ekologiniais produktais, leidžiamais ekologinėje auginimo sistemoje, ir augalų apsaugai naudojant biopesticidus. Ekologinėje ir tradicinėje žirnių auginimo sistemose ligų ir kenkėjų: fuzariozinio vytulio (*Fusarium oxysporum* f. sp. *pisi*), bakterinės dėmėtligės (*Pseudomonas syringae* pv. *pisi*), alternariozės (*Alternaria* spp.), netikrosios miltligės (*Peronospora pisi*) ir žirninių vaisėdžių rūšių (*Laspeyresia* spp.), paplitimas buvo mažas. Taikant ekologinę auginimo sistemą nustatytas didesnis askochitozės (*Ascochita pisi*) paplitimas ir didesnis procentas sėklų, pažeistų žirninių grūdinukų (*Bruchus pisi*). Patogenų ir kenkėjų įtaka tirtų linijų žirniams buvo ribota dėl biohumuso ir biopesticidų panaudojimo. Taikant ekologinę sistemą augintų žirnių absoliutus sėklų svoris buvo mažesnis nei augintų tradicinėje sistemoje. Buvo nustatytas didelis linijų 1857_3 ir 73_{10} žirnių, augintų ekologinėje sistemoje, sėklų daigumas.

Reikšminiai žodžiai: ekologinis ūkininkavimas, derlius, kenkėjai, ligos, *Pisum sativum*, selekcija.